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NOTES ON THE KAOLIN- AND CLAY-DEPOSITS OF NORTH CAROLINA.*

BY J. A. HOLMES, CHAPEL HILL, N. C.

As the Appalachian mountains reach their maximum development in western North Carolina, we find also in that region indications of extensive dynamic disturbances and alterations undergone by the rocks in connection with these mountain uplifts. Among the minor results of these changes have been the formation of numerous dikes of "veins" of exceedingly coarse granitic materials, which in some places are mined for the mica which they contain, and in other places are quarried for kaolin. These dikes are filled with quartz, feldspar and mica, in varying proportions, very coarsely crystalized. Sometimes the mica (generally muscovite), sometimes the feldspar (generally albite or orthoclase), predominates. When the mica is present in considerable quantity and in large crystals, the dyke is usually spoken of as a mica-vein, and is often worked for mica. Sometimes these crystals of mica occur on one side or the other, sometimes on both sides,

* From the Transactions of the Am. Inst. of Mining Engineers, Vol. XXIV, 1895.

and sometimes they are largely concentrated in the middle of the vein, or, it may be, distributed throughout the dike with a considerable degree of uniformity. In many cases the crystals are too small and few to permit of the working of the vein as a mica mine; in other cases very little mica is present, and the feldspar constitutes the larger part of the material. This feldspar of the dikes undergoes, through the weathering action of the atmosphere, certain chemical changes resulting in its alteration from feldspar into kaolinite—the kaolin of commerce.

These dikes vary considerably in size, ranging from a few inches to several hundred feet in thickness, and up to many hundred yards in length. They are generally parallel to the schistosity of the crystalline rocks, which, however, in some cases, they cross at various angles.

The kaolin in those dikes which occur in the Unaka or Smoky mountains is said to have been mined by the Indians, "packed" across the country to the seaboard, and shipped to England as early as the 17th century. From one of them, near Webster in Jackson Conntv, kaolin is now mined (by the Harris Clay Co.) and shipped to Trenton, N. J. and other centers for the manufacture of fine pottery. This Webster dike contains very little mica and comparatively little quartz. It has a maximum width of about 300 feet, and has been traced for a length of more than a half mile. It is mined to a depth of from 60 to 120 feet, below which the original feldspar has not been sufficiently altered, and is too hard for economic mining. The kaolin is brought from the mine, crushed, and washed in a series of settling-vats, for the purpose of separating it from the granular quartz. Its plasticity is increased

both by washing and by the subsequent grinding which it receives. The following analysis* of the washed and dried product ready for shipment shows the general character of such material.

ANALYSIS OF KAOLIN, HARRIS MINE, NEAR WEBSTER, N. C.

	Per cent.
Free silica, silicic acid and sand	2.28
Combined silica	41.62
Alumina	40.66
Oxide of iron	0.14
Alkalies	0.46
Lime	none
Magnesia	trace
Combined water	14.00
Moisture	0.84
Titanic acid	none
Total	100.00

Many similar but smaller feldspathic and kaolin dikes are found in the various other counties west of the Blue Ridge, and at a number of these the feldspar has been altered into kaolin for considerable depths below the surface, but none of them have been worked extensively for either the feldspar or the kaolin, except the Harris clay-mine just mentioned. Also at various points in the Piedmont Plateau, which extends east of the Blue Ridge for from 150 to 200 miles, there are to be found deposits of this kaolin which have doubtless originated in much the same way as those west of the Blue Ridge; but none of these are now worked to any considerable extent. The age of these crystalline rocks in the Piedmont plateau and the mountain

* Made for the Harris Clay Co. of Dillsboro, N. C. at the Pittsburgh Pa. Testing Laboratory.

counties, and the exact time at which the disturbance took place which resulted in the formation of these massive granitic dikes is, as yet, a matter of doubt.

So numerous are these dikes in certain places, and so long have their feldspars been undergoing surface transformation into residual kaolin or clay, that one might expect to find in this region, as in some other countries, sedimentary deposits of this material which had been transported for greater or less distances; but when we bear in mind the general elevation in the mountain-region and the consequent rapidity of its streams, we can readily understand that this product of denudation would scarcely be deposited until it had been carried so great a distance from the original source as to be lost by commingling in the lowlands with larger proportions of other and different materials.

Along the borders of the Piedmont plateau-region there are occasionally found deposits of this kaolin material which has evidently been carried but a short distance. Such occurrences are more extensively known on the western border of the Coastal Plain region, mainly in the Potomac formation, as in the neighborhood of Aiken, S. C., and Augusta, Ga., and in many other places, where considerable deposits of this kaolin-material occur, both in the form of arkose (where the kaolin is still mixed with the quartz and mica of the original granitic formation) and in the clay-beds, where it has been more completely sorted, and the kaolin has been separated from the coarser materials, so as to form extensive beds of what is locally termed "china"- or potters-clay. In some cases, in the arkose material just referred to, the partially decayed crystals of feldspar are frequently found with the kaolinization incomplete; and mingled with these are fragments of

other minerals, transported from the débris of the crystalline rocks occurring along the borders of the Piedmont plateau, not many miles away.

The points above noted may explain, perhaps, the confusion which has arisen in the use of the term "kaolin." The applicability of this name to the material described above as having its origin directly in the large granitic dikes, I suppose no one will question. But if the residual material of dike-decomposition has been transported a short distance by the streams and deposited without further sorting the materials, or if it has been transported to a much greater distance, so that the sorting has become fairly complete, and the mineral kaolinite, while separated from the quartz and mica of the original mass remains unmixed with other foreign materials, so as to be itself fairly pure,—the question arises whether the term kaolin is still applicable in both cases; and if so, to what extent, in its transportation and sorting, this material may become mixed with other foreign materials resulting from the decay of crystalline rocks in the region through which it has been transported, before the term kaolin would become inapplicable. In other words, where, in such a case, should we discontinue the use of the word "kaolin" and apply the broader term "clay"? Further discussion of this question cannot be attempted in this paper; but it is mentioned here because the writer has recently heard a number of complaints from practical potters who use the clay-material on a commercial scale, that many people throughout the country were designating all the samples of their material forwarded as "kaolin," regardless of their color and other characteristics.

Through many places, both in the mountain- and the

Piedmont plateau-regions, there are deposits of clay resulting from the decay of granites, gneisses and crystalline schists. Many of these have a structure which would indicate that the materials have been transported for greater or less distances. But in, perhaps, many other cases, the materials have evidently decayed in place, since the gradations can be traced from the clay down into the partly altered rock below. These clays, of course, vary in composition with the character of the rocks from which they have been formed. They have frequently a reddish or yellowish color, due to the oxides of iron present, though in many places the colors are much lighter, the iron having been removed through the action of organic matter. As will be seen from the above statement, these may be classed as partly residual clays and partly transported clays. They have been worked on a small scale in many places for brick; and in a few places, as at Biltmore (Buncombe County) and at Pomona (Guilford County) they have been used in the manufacture of tile-, drain-, and sewer-pipes; also at Pomona for fire-brick; and near Grover (Gaston County) for fire-brick and vitrified or paving-brick.

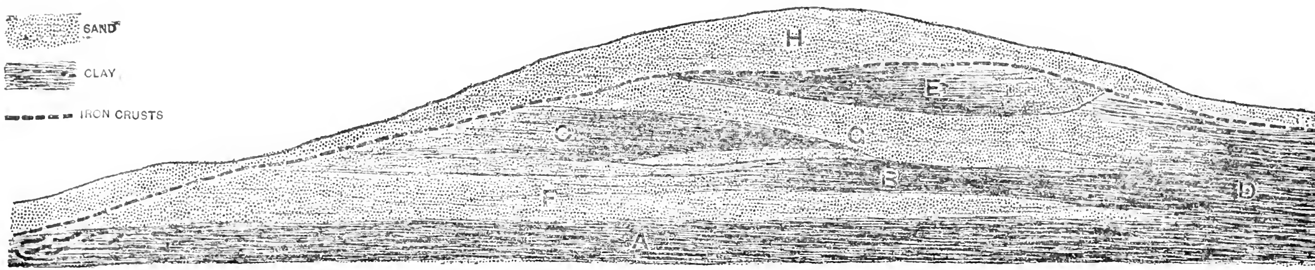
The age of these transported clays of the mountain- and Piedmont plateau-counties is unknown. Some of them, upon careful investigation, may be shown to belong to certain definite recent geologic periods; but most of them, probably, cannot be ascribed to any definite geologic time, but must be attributed simply to local conditions; and their age is probably recent. The clay and brick-loam deposits along the river terraces of the mountain and Piedmont counties which, in many places, are well adapted to the manufacture of brick, may be Columbian or older in age.

Those residual clays of these regions which have been formed *in situ* are the result of the processes of decay, the operation of which cannot be limited to any definite epoch, but may be ascribed, in general, to recent geologic time.

The most extensive beds of clay known in North Carolina are those found in the Coastal Plain region. In the Potomac (lower Cretaceous) formation, there are extensive beds of laminated, dark-colored clays, exposed along the banks of rivers crossing the coastal-plain region, notably on the Cape Fear river, for fifty miles below Fayetteville. These clays are usually dark in color, owing to the vegetable matter which they contain; and, in some cases, they are highly lignitic. The thin laminae are frequently separated by still thinner partings of sand; and frequently within a short distance (from a few feet to a few hundred feet) the clay-laminae become thin and disappear, while the sand-partings gradually thicken, so that the whole assumes the character of a sand-bed instead of a clay-bed. This feature, which indicates plainly the shifting conditions under which these deposits were laid down in certain localities, illustrated in the accompanying sketch of the river bluff at Prospect Hall on the Cape Fear river, 21½ miles below Fayetteville.

In some portions of these clay-beds, pyrite occurs in such quantities as would probably interfere with their industrial use; but the larger portion of the deposits appears to be free from pyrite, and will probably prove to possess considerable economic value. Thus far no efforts have been made to utilize them; but both analytic and practical tests of them are being made at the present time.

Along the western border of the Coastal Plain re-



Clay beds in Prospect Hall Bluff, Cape Fear River.

A, clay 10 feet thick above medium-low water; B, clay 6 to 8 feet thick; C, clay 12 to 15 feet thick; D, clay 40 feet thick; E, clay 15 feet thick; F, laminated sand with thin clay partings; G, sand with thin clay partings, 12 feet thick; H, laminated yellowish and whitish sand with thin loam partings, 15 to 18 feet thick, becoming loose, nearly pure whitish sand near the surface. [Except the left end—down stream—the iron crusts are much more prominent there than is indicated in the drawing.

gion, especially in Moore and Harnett Counties, there are limited exposures of silicious Eocene deposits (overlying the Potomac series, and capping some of the sand-hills) which have recently been tested for fire-brick with very satisfactory results. These deposits are from 5 to 15 or more feet in thickness, and are overlaid by but a few feet of loose sand. The following analysis of this material, collected two miles N. E. of Spout Springs,* shows its general composition.

ANALYSIS OF "FIRE-CLAY" (EOCENE) TWO MILES N. E. OF SPOUT SPRINGS, N. C.

Silica	87.70
Alumina	3.29
Ferric oxide	2.81
Lime	0.48
Magnesia	0.40
Alkaline chlorides	1.48
Loss on ignition	3.15
Total	99.31

Among the Miocene deposits, there are, in places along the river-bluffs of the Coastal Plain region, especially on the Roanoke and the Tar, somewhat extensive exposures of "blue marl," a calcareous clay which may prove to be of some value, but of which no practical tests have yet been made-

The Lafayette (Pliocene) materials, which are spread over so large a portion of the Coastal Plain region, are generally gravelly or sandy in composition, with a large admixture of loam in many places. No extensive deposits of clay have been observed among the materials of this formation, though doubtless limited deposits of clay will be discovered as more extensive explorations are made.

* Made in the laboratory of the N. C. Geological Survey.

The later deposits bordering the river-courses and covering the river-terraces, at elevations from 20 to 100 feet above sea-level, which may be designated as the river phase of the Columbian formation, contain extensive beds of sandy clays and brick-loams; and, throughout the entire Coastal Plain region of the South Atlantic States, it is these deposits which are most largely used in the manufacture of brick.

A DESCRIPTION OF SOME OF THE MUSCLES OF THE CAT.

BY H. V. WILSON AND G. H. KIRBY.

The most complete account extant of the cat's muscular system is that found in Strauss-Durckheim's Anatomie du Chat[1]. The expense of the work, however, renders it inaccessible to many. And in spite of the great beauty and general accuracy of the plates, it is not well adapted to the purposes of the dissector, owing chiefly to the length and detailed character of the descriptions (e. g. *psoas-muscles* and *quadratus lumborum*) and in a less degree to what we regard as the misleading subdivision of the muscles of certain groups (e. g. *pectoral* group). With due deference to such a magnificent work, the results of dissection lead us to differ from Strauss-Durckheim in certain points of detail, to some of which attention is called.

Perhaps the most generally useful work on the cat is that of Mivart[2]. The descriptions and accompanying

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1 Strauss-Durckheim. Anatomie Descriptive et Comparative du Chat. 2 vols. and Atlas. Paris, 1845.

2 St. George Mivart. The Cat. New York, 1895 (latest issue).

figures enable the dissector to identify without trouble most of the muscles. But this part of the work, at least, contains too many inaccuracies to make it a safe guide. In like manner the value of a recently published hand-book[3] is much impaired by inaccurate statements regarding the origin and insertion of many of the muscles described.

Finally, that most original and valuable work, the "Anatomical Technology," only includes a description of the muscles of the chest, shoulder and fore-leg. The accurate nature of all the descriptions in the "Technology" has long been recognized, and the few points in which our description of the pectoral muscles differs from that of Wilder and Gage[4], are doubtless varying points. In spite, however, of its accuracy, the account given in the "Technology" of the cat pectorals seems to us an unnecessarily difficult one to follow. This is in part due to the manner in which the group is subdivided.

ABDOMINAL MUSCLES.

External oblique. This muscle arises along its external border from the nine last ribs and from the lumbar fascia. The attachments to the ribs interdigitate with the slips of the *serratus magnus*, and lie beneath the *latissimus dorsi.* The lumbar fascia from which the muscle arises is the superficial fascia which may be peeled from the underlying *transversalis abdominis*, and may be traced to the spinous processes of the vertebrae.

Along its inner border the muscle passes into a broad,

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3 Gorham and Tower. A Laboratory Guide for the Dissection of the Cat. New York, 1895.

4 Wilder and Gage. Anatomical Technology as applied to the Domestic Cat: New York and Chicago, 1882.

thin aponeurosis, which is closely bound to the subjacent *rectus abdominis*, and unites with its fellcw of the opposite side along the *linea alba*. This aponeurosis extends from the *symphysis pubis*, to which it is attached, forwards to the level of the ninth costal cartilage. The anterior part of the aponeurosis underlies (is dorsal to) the most posterior *pectoral* muscle. The posterior and external edge of the aponeurosis, extending from the *symphysis pubis* obliquely dorsally and posteriorly, is known as *Poupart's ligament*. Near the symphysis the aponeurosis is perforated by an aperture, the *external abdominal ring*, which is the external opening of the *inguinal canal*. This aperture lies between *Poupart's ligament* and the rest of the aponeurosis.

Synonymy. *Oblique-interne abdominal*, S.–D., vol. II, p. 314; *external oblique*, M., p. 141; *external oblique*, G. & T., p. 28.

Mivart is wrong in stating that the muscle arises from the *eight* last ribs; and that Poupart's ligament extends from the symphysis pubis to the *Ilium*. The latter statement is true of human anatomy; but in the cat the ligament (or free edge of the aponeurosis) passes in front of the ilium, having no connection with it. Gorham and Tower commit the same mistakes.

The account given of the muscle both by Mivart and Gorham and Tower would indicate that Poupart's ligament is something distinct from the tendon or aponeurosis of the *external oblique*. Mivart in this matter, is not intelligible. He states that the aponeurosis divides into external and internal tendons, between which lies the "external abdominal ring," bounded in front by Poupart's ligament. Possibly the "in front" is a misprint, for the ligament lies *behind* the abdominal ring.

Internal oblique. The muscle arises along its external border from the superficial lumbar fascia, directly beneath the origin of the *external oblique*; and from the ventral margin of the ilium. At its posterior end the muscle arises from the pubis.

The fibres run anteriorly and ventrally. At some distance external to the *rectus abdominis*, they pass into a thin aponeurosis, which throughout its anterior extent is firmly attached to the underlying (*i. e.* dorsal) *transversalis abdominis*, and is thus dorsal to the *rectus abdominis*. Throughout its posterior extent the aponeurosis extends ventrally over the *rectus abdominis*, being indistinguishably united with the aponeurosis of the *external oblique*.

At its anterior end, near the dorsal border, the muscle is attached directly by its fibres to the last rib. The muscle may here be seen to be a continuation of the layer formed by the *internal intercostals*. The *internal intercostal* between the 12th and 13th ribs, is in fact *directly* continuous with the *internal obiique*.

Synonymy. *Oblique-interne abdominal*, S.-D., vol. II, p. 315; *internal oblique*, M., p. 142; *internal oblique*. G. & T., p. 29.

Mivart is wrong in stating the muscle to be "inserted inside the cartilages of the last ribs." Gorham and Tower inexactly state "the more anterior fibres to be inserted on the cartilages of the *ribs*." According to Strauss-Durckheim the relations of the aponeurosis of the *internal oblique* to the *rectus* are quite the same as in human anatomy, in that anteriorly the aponeurosis splits into two layers which ensheathe the *rectus* dorsally and ventrally. This ventral limb of the anterior part of rectus sheath, if it ever is present, must con-

sist of a very few and delicate fibres. It was not observed in any of the several cats dissected by us.

Transversalis abdominis. The muscle arises along its dorsal border, just beneath the *erectores spinae*, from the fascia covering the ventral surface of the latter (middle layer of the lumbar fascia in human anatomy). It also arises from the cartilages of the false ribs and from the ventral margin of the ilium.

Along its inner border it is anteriorly, and for the greater part of its course, inserted into a broad, thin aponeurosis which lies dorsal to the *rectus abdominis*, and is continuous with its fellow of the opposite side as an independent aponeurosis. Posteriorly, however, the fibres of the muscle pass into a fascia, lying ventral to the *rectus abdominis*, and inseparably united with the combined aponeuroses of the *external* and *internal oblique*.

Synonymy. *Latitudinal*, S.-D., vol. II, p. 317; *transversalis*, M., p. 142; *transversalis abdominis*, G. & T., p. 29.

According to Mivart the muscle ends in an aponeurosis lying dorsal to the *rectus*. Gorham and Tower give the muscle as ending "in an aponeurosis beneath the rectus." Both authors thus overlook the important difference in position between the anterior and posterior portions of the aponeurosis. Strauss-Durckheim evidently recognizes this difference, though he does not explicitly state it. He designates the aponeurosis as the third layer of the abdominal aponeurosis, and goes on to say: "Ce feuillet—s'unit á celui de l'oblique interne, et se comporte du reste comme lui."

Rectus abdominis. The muscle arises from the symphysis pubis. It is completely separated by the connective tissue of the *linea alba* from its fellow of the

opposite side; and is inserted on the first, second and third ribs, the chief insertion being on the first.

At about the level of the ensiform cartilage, the muscle gives off a small slip, which is inserted along with its fellow of the opposite side, into the aponeuroses of the *external obliques*, in the median line, beneath the posterior (fifth) *pectorals*.

The *rectus abdominis* is ensheathed in the aponeuroses of the two *obliques* and the *transversalis*. Posteriorly all these aponeuroses lie ventral to it. Anteriorly the aponeurosis of the *external oblique* is ventral, but the aponeuroses of the *internal oblique* and *transversalis* are dorsal to it.

Synonomy. *Droit-abdominal*, S.-D., vol. II, p. 307; *rectus abdominis*, M., p. 142; *rectus abdominis*, G. & T., p. 29.

The slip given off in region of ensiform cartilage, is not mentioned by the writers cited above. It probably corresponds to the fibres said to be attached to the ensiform cartilage in human anatomy.*

* Quain's Anatomy, 10 ed., vol. II, pt. 2, p, 334.

Our account of the rectus sheath differs from that of Strauss-Durckheim, in that we do not find the aponeurosis of the *internal oblique* dividing into ventral and dorsal limbs which embrace the *rectus* anteriorly, as already mentioned in connection with the *internal oblique*. Mivart, and Gorham and Tower, overlook the insertion of the posterior part of the *transversalis*, and thus give an imperfect account of the sheath.

PECTORAL MUSCLES.

The pectoral muscles form a triangular mass on the front of the chest, running from the median line of the body to the arm. The mass is divisible into five dis-

tinct muscles. These may be arranged in two groups. One group includes the first, second, and third *pectorals*, all of which muscles arise from the anterior portion of the sternum and run outwards. This group corresponds in a general way with the more superficial (*P. major*) of the two *pectorals* of man. The other group includes the fourth and fifth *pectorals*, which muscles in general pursue a course from the sternum outwards and *anteriorly* to the proximal end of the humerus. This group corresponds with the inner human *pectoral* (*P. minor*). In a general way it may be said that the muscles of one group cross those of the other. (On this crossing of the *pectoral* muscles, see Wilder and Gage, p. 235).

The first pectoral is the most superficial of the group. It is rather narrow and band-shaped, and arises from the presternum and the raphé in front of the latter. The raphé in question is the median connective tissue septum between the posterior portions of the *sternomastoids*, and between the anterior portions of the second *pectorals*. The greater part of the muscle arises from the mid-ventral line of the presternum, along the anterior three fourths of that bone. Only the extreme anterior part arises from the raphé.

Part of the muscle is inserted along with a shoulder muscle, the *cephalo-humeral*. Part is inserted into the fascia of the fore-arm, along with a slip from the *third pectoral*.

Synonymy. *Pecto-antebrachial*, S.-D., vol. II, p. 352 (the slip from the *third pectoral* is regarded as the "second chef" of the *pectoantebrachial*) ;*pecto-antebrachial*, W. & G., p. 236 (above-mentioned slip is counted as the "caudal division of the *pecto-antebra-*

chial"); *pectoralis, part I.*, M., p. 145; *pectoralis, part a*, G. & T., p. 30.

There is no actual union, in cases at least, between the muscular part of the distal end of the slip from the *third pectoral* and the *epitrochlear*, as W. & G. state (p. 238). The slip is in close juxtaposition to the *epitrochlear* along its posterior border.

The origin of the muscle, as given by Mivart, is inaccurate: "from beneath the manubrium and attachment of the first two costal cartilages." Gorham and Tower give the same origin as Mivart.

The second pectoral is a wider muscle than the first. It is superficial just in front and just behind the first, but the greater part of it is covered by the latter. It arises from the presternum and the median raphé, above referred to. The muscle arises from the mid-ventral line of the presternum along the entire length of the latter. The anterior portion arising from the raphé is noticeably thicker than the rest of the muscle.

The chief insertion is on the outer surface of the humerus, along the middle third of that bone, external to the attachment of the *third pectoral.* The fibres lying along the posterior border of the muscle are inserted into the bicipital arch.

Synonymy. *Premier chef du large pectoral*, S.-D., vol. II, p. 343; *lamina ectalis of the ectopectoralis*, W. & G., p. 238; *pectoralis, part 5* (partially), M., p. 147; *pectoralis, part e* (partially), G. & T., p. 31.

Mivart's *part 5* apparently only corresponds to the anterior portion of our *second pectoral.* M. is inaccurate regarding the origin, which he says is from the manubrium: "The *fifth* * * is the most anterior. It arises from the manubrium." The origin from the median

raphé is thus overlooked. Gorham & Tower agree with Mivart.

The third pectoral is a wide muscle. Anteriorly it is covered by the *first* and *second pectorals*, but the posterior half or more is superficial. It arises from the above-mentioned raphé, from the presternum, and from the next two sternebrae, its origin thus extending as far back as the attachment of the fourth costal cartilage to the sternum. Only the extreme anterior portion of the muscle arises from the raphé. Behind these fibres, the muscle arises from the ventro-lateral surface of the presternum, along the whole length of the latter. The portion of the muscle arising from the next two divisions (sternebrae) of the sternum is superficial.

The chief insertion is on the humerus, and is a very long one. The proximal part of this insertion is by a thin aponeurosis to the extreme outer surface of the humerus. The middle part is directly by muscle fibres to the ventral surface of the humerus. The distal part is again by aponeurosis to the ventral surface of the humerus.

The most anterior fibres of the muscle are inserted into a small tendon which quickly divides. One division passes externally to the shoulder joint, and is attached to the outer end of the clavicle. The other division passes internally to the shoulder-joint, and terminates in the fascia on the mesal surface of the scapula in the interval between the *supra-spinatus* and the *sub-scapularis*.

The muscle is also inserted into the bicipital arch. As has already been mentioned, a slip lying along the posterior border of this muscle separates from it, and is inserted along with the *first pectoral*.

Synonomy. *Second chef du large pectoral*, S.-D.,

vol. II, p. 343; *lamina cutalis of the ectopectoralis*, W. & G., pp. 239–240; *pectoralis, part 2* (partially), M., p. 145; *pectoralis, part b* (partially), G. & T., p. 30.

Wilder and Gage divide the muscle into two subdivisions, cephalic and caudal. This division seems to us an arbitrary one. We do not find the muscle naturally so divided. Mivart's *part 2* apparently includes our *third pectoral* and the posterior part of our *second pectoral*.

The fourth pectoral is a wide, thick mass, being much the largest muscle of the group. At its origin it is a single, undivided muscle, though distally it splits into two subdivisions, anterior and posterior, having different insertions.

The muscle arises from nearly the whole sternum. The origin begins just posterior to the presternum, and includes all the mesosternebrae and the anterior two-thirds of the xiphi-sternum.

Of the two subdivisions into which the muscle splits distally, the anterior is inserted on the great tuberosity of the humerus, coming here into close connection with the *supra-spinatus*. The insertion of the posterior subdivision is complex. The chief part is inserted on the proximal half of the ventral surface of the shaft of the humerus, anteriorly by muscle fibres, posteriorly by aponeurosis. The fibres forming the posterior portion of this subdivision are inserted, along with the *latissimus dorsi*, into the bicipital arch. Into the posterior border of this subdivision run fibres belonging to the great cutaneous muscle, the *panniculus carnosus*.

Synonomy. *Sterno-trochiterien* plus *premier chef du grand pectoral*, S.-D., p. 337, p. 341; *ento-pectoralis*, W. & G., p. 241, *pectoralis, part 3*, M. p. 147; *pectoralis, part c*, G. & T., p. 30.

Mivart again gives an inaccurate origin: "from the sternum between the second and sixth costal cartilages." Gorham and Tower agree with Mivart.

The fifth pectoral, the most posterior member of the group, is long and comparatively narrow. The muscle arises from the aponeurosis of the *external oblique*, which here forms a ventral covering for the *rectus abdominis*. In the anterior portion of the origin, the muscle fibres arise directly from the median line, where there is raphé common to the several muscles of the abdominal wall. Posteriorly, however, the muscle fibres arise from the aponeurosis, along a line which extends obliquely, in a dorsal and posterior direction, from the mid-ventral line.

The muscle is inserted by aponeurosis both into the bicipital arch, and the proximal end of the humerus. The latter insertion includes both tuberosities.

Synonomy. *Second chef du grand pectoral*, S.-D., vol. II, p. 341; *xiphi-humeralis*, W. & G., p. 244; *pectoralis, part 4*, M., p. 147; *pectorals, part d*, G. & T., p. 31.

The details of the origin of this muscle are doubtless variable. Wilder & Gage state that the muscle fibres are connected to the median raphé by a thin, wide tendon. Mivart is, however, entirely mistaken as to the origin. He gives the muscle as arising "from the sternum between the fifth costal cartilage and the root of the xiphoid." Gorham and Tower give the same origin as Mivart: "from the sternum between the cartilages of the fifth and eighth ribs."

SOME MUSCLES OF THE HIND-LEG AND BACK.

Tensor vaginae femoris. The muscle arises from the anterior end of the ilium, and from the fascia ex-

tending between this muscle and the anterior division of the *gluteus maximus*. This fascia is closely bound to the underlying *gluteus medius*, and is continuous with the dense fascia covering the sacrum dorsally.

The muscle is inserted by a fascia (*fascia lata*), which covers the external and anterior surface of the thigh, and dipping in between the *vastus externus* and the *adductor*, is attached to the outer surface of the femur, along nearly its whole length.

The *tensor vaginae* near its origin, is inseparably connected (in cases at least) with the *gluteus medius*. It is also directly continuous posteriorly with the anterior division of the *gluteus maximus*, the two actually forming a single muscle.

Synonymy. *Couturier et droit interne* plus the *fascialis*, S.-D., vol. II, p. 402, p. 403; *tensor vaginae femoris*, M., p. 154; *ditto*, G. & T., p. 39.

Gluteus maximus. The muscle is divided into two portions. The anterior arises directly by muscle fibres from the transverse process (lateral mass) of the third sacral vertebra, and the transverse process of the first caudal vertebra, and from the fascia covering the *gluteus medius* and the sacral region. It is inserted into the femur, just below the great trochanter, by means of the extreme upper end of the *fascia lata*, and by a few independent fibrous strands, noticeable in old subjects.

The posterior part arises directly by muscle fibres from the transverse processes of the first two caudal vertebrae. It is inserted into the fascia lata.

It is only in young subjects that the two parts of the muscle are distinct at the origin. In older subjects, the muscle has a continuous origin from the sacral fascia, sacrum and caudal vertebrae.

Synonymy. Fesser plus the paraméral, S.-D., vol. II, p. 395; gluteus maximus, M., p. 154; gluteus maximus, G. & T., p. 39.

The fesser of S.-D. corresponds to our anterior portion of the muscle, though S.-D. omits the origin from the third sacral vertebra. The paraméral of S.-D. corresponds to our posterior portion. Here again we differ slightly from S.-D. regarding the origin, which according to him is from the second and third caudal vertebrae. The difference may easily be due to variation.

Quadratus lumborum. The muscle arises directly by its fibres, and also by tendinous origins, from the dorsal part of the anterior border of the ilium; and from the transverse processes of all the lumbar vertebrae. The fibres of the muscle run forwards and inwards (mesially), and are inserted both directly and by means of narrow tendons into the centra of all the lumbar and the posterior three dorsal vertebrae.

This muscle exhibits a remnant of the metamerism, characteristic of the trunk muscles of the embryo and lower vertebrates, in that the narrow tendons are inserted successively into the bodies of the vertebrae, thus imperfectly dividing the muscle into myotomes.

Synonymy. Longs-sous-intertransversaires de lombes, S.-D., vol. II, p. 282; quadratus lumborum, M., p. 156.

Psoas magnus. The muscle arises directly by its fibres from the dorsal part of the anterior border of the ilium; by a few fibres from the transverse process of the last lumbar vertebra; at the extreme anterior end, externally, from the aponeurosis covering the quadratus lumborum; along its inner border from the centra of the lumbar vertebrae. Over its dorsal sur-

face the fibres of the muscle pass into the quadratus lumborum, with which muscle the psoas magnus is blended anteriorly, excepting that part which arises from the aponeurosis covering the former. The muscle is inserted on the lesser trochanter of the femur.

Synonomy. Psoas, S.-D., vol. II, p. 406; psoas magnus plus iliacus, M., p. 156;, psoas magnus, G. & T., p. 42.

The fibres arising from the anterior border of the ilium correspond to Mivart's iliacus. M. is wrong in stating that the muscle arises "from the transverse processes of all the lumbar vertebrae." Gorham and Tower make the same statement.

Psoas parvus. This muscle may be regarded as a part of the psoas magnus, which has a separate insertion. It is indistinguishably united with the p. magnus throughout its anterior portion, and thus has with the latter a common origin. It is inserted by a tendon on the rim of the pelvis, at the ileo-pectineal eminence.

Synonymy. Mipsoas, S.-D., vol. 2. p. 287; psoas parvus, M., p. 156.

University of North Caroiina,
February, 1896.

ORIGIN OF THE PERIDOTITES OF THE SOUTHERN APPALACHIANS.*

BY J. VOLNEY LEWIS.

INTRODUCTORY NOTE.

It was my privilege to spend the summer months of 1893, 1894 and a part of 1895 in mapping and studying in the field that portion of the Appalachian belt of peridotites which extends across North Carolina, almost parallel to its western boundary, from Virginia to Georgia and western South Carolina. A number of excursions were also made to other portions of the belt in Georgia and Pennsylvania. The work was done in the preparation of a report on "Corundum and the Basic Magnesian Rocks of Western North Carolina," which has just appeared as Bulletin No. 11 of the State Geological Survey. The Bulletin was confined to a presentation of the field results; the various rock types are described and the distribution and modes of occurrence of the peridotites and corundum are given in some detail.

Discussion of doubtful points, and especially of those already involved in controversy, was withheld for a future publication, in which the results of microscopic study and other laboratory work on these rocks would be presented, with such discussion of origin and other relations as these results might justify. A portion of this work has already been done, and some interesting results have been attained, but they will

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hardly be ready to put into systematic form for publication before the close of the year. A number of points have been brought out in the field-work, however, that are considered to have sufficient bearing on the origin of the peridotites to warrant their presentation.

THE ROCKS AND THEIR RELATIONS.

The accompanying map of the Appalachian crystalline belt (Plate I) shows the distribution of the peridotites throughout this region. In Pennsylvania and Maryland the basic magnesian rocks, whether originally peridotites or pyroxenites, have been entirely altered into serpentine; and hence have lost most of their original characteristics. The Virginia occurrences are not so well known. Rogers' Reports show that many of them have altered into serpentine and talcose rocks, and this is doubtless true of the great majority of outcrops. Fresh olivine rocks, however, are found passing over into that state from Alleghany county, North Carolina, and they are doubtless to be found at a number of places on the belt, south of Lynchburg.

With few exceptions, the peridotites south of Virginia are remarkably fresh, the alterations consisting, in the majority of cases, of scarcely more than surface discoloration or an occasional local change into massive serpentine.

The country rocks of the region are gneisses and mica schists, sometimes bearing considerable bodies of sheared and massive granites. The lamination has a prevailing strike of north 30° to 45° east and dips at high angles either northwest or southeast, often passing through the vertical from one to the other within the space of a few feet. Constituting a small proportion of the area of this region are the rocks of the per-

idotite belt, which occur typically in blunt lenticular form with a longer axis of from a few hundred to a thousand feet or more and oriented with the lamination in the surrounding gneiss. Sometimes they take the form of narrow strips two or three miles in length.*

Three types of magnesian rocks are found in this belt: namely, *peridotites*, *pyroxenites*, and *amphibolites*, characterized by the predominance of olivine, pyroxene and hornblende respectively. Pyroxenites and amphibolite frequently occur in small masses in close association with peridotites, and sometimes form important independent masses, but probably more than nine-tenths of the outcrops are peridotites.

The Peridotites.—The accepted classification of these rocks is used here merely as a matter of convenience. No such division into distinct classes is possible in the field; and the names here given represent simply mineralogic varieties of the same petrographic unit. Occasionally these varieties form separate masses, but generally they grade insensibly into each other, and sometimes within the limits of a single small outcrop. *Dunite*, essentially the pure olivine rock, with accessory chromite or picotite, is by far the most important, since it constitutes almost the entire body of a great majority of outcrops. *Harzburgite* (Saxonite), the olivine-enstatite rock, constitutes large masses in some of the northwestern counties of North Carolina, but it is usually found as a local variety of dunite. "Peridosteatite" and "glinkite" seem to be only partially altered forms of this rock, consisting of large olivine crystals (or serpentine) and talc. *Amphibole-picrite*,

* See map (Plate I) published in Bull. 11, N. C. Geological Survey, 1895.

the olivine-actinolite variety, has been observed only in connection with dunite, though some chloritic olivine rocks are doubtless altered forms of this variety. *Troctolite* (forellenstein) consists essentially of olivine and anorthite, with zones of intermediate fibrous minerals always separating them, and sometimes also bears large dark hornblende. By gradual transition it passes, on the one hand, into dunite, and, on the other, into the feldspar type *anorthosite*.

The Pyroxenites.—This class is represented by two types, which seem to be quite distinct, as no transitional forms have yet been found. *Enstatite-rock*, as the name indicates, is composed of orthorhombic pyroxene, and seldom contains any other mineral in prominent proportions. It often occurs in small masses with dunite and harzburgite, though considerable outcrops in some localities are composed of it entirely. In some of these instances there is apparently evidence of its origin from peridotites. *Websterite*, the enstatite-diopside type, is found in the midst of the peridotites about Webster, Jackson county, North Carolina. This type was first recognized and described by the late Dr. G. H. Williams,* and similar rocks were studied from Baltimore county, Maryland, where transitional forms were found connecting it with peridotites, bronzitite, gabbros, and norite. At the Webster locality, however, no such intermediate types have been observed.

Amphibolite.—Only one type of this class has been found in the peridotite belt. It is composed of a brilliant, grass-green, aluminous amphibole, which often bears considerable anorthite and is only occasionally

* Am. Geologist, VI, 1890, 40–49.

massive, generally presenting a gneissic lamination. The amphibole constituent has long been erroneously called "smaragdite," solely on account of its color. Analyses show over 17 per cent. of alumina, and Professor Dana calls it *edenite* in his new "Systemof Mineralogy." This rock forms dikes in the peridotites at Buck Creek, Clay county, North Carolina, and is associated with peridotites in many places in this and the neighboring counties of Georgia.

No absolute contacts have been observed between the peridotites or pyroxenites and the enclosing gneiss. There is always a border of schistose talc, from two to three feet in thickness, developed between them. Often there is also a variable zone of chlorite or vermiculite, or of both together, intervening between the talc and the peridotite mass; and in many cases this bears corundum in considerable quantity.*

EVIDENCE BEARING ON ORIGIN.

We have seen that the peridctites occur, as a rule, in lenticular masses and sheets, having their longer axes oriented with the lamination of the gneisses and schists of the country. Some of these lenses are short and blunt, and occasionally the outcrops present a very irregular outline and cover areas of several hundred acres, as at Buck Creek, in Clay county, North Carolina (Plate II). The smaller masses are in just the form one would expect to find in small intrusions of molten magma into thoroughly laminated crystalline

* For more detailed description of the rocks and modes of occurrence and distribution of both the peridotites and corundum, the reader is referred to "Corundum and the Basic Magnesian Rocks of Western North Carolina," *Bulletin 11, N. C. Geol. Survey*, and to "Corundum of the Appalachian Crystalline Belt," *Trans. Am. Inst. Mining Engineers*, XXV, Atlanta Meeting, 1895.

rocks; and the more irregular outlines would naturally have been produced by larger intrusions accompanied or preceded by intense folding and contorsion of the gneisses. Furthermore, both the irregular and the more typical lenticular outcrops frequently present a forked outline or send off small apophyses into the gneiss in such a way as would be wholly inexplicable in a rock of sedimentary origin. Prominent examples of this character are presented on the maps of Buck Creek, Corundum Hill and Webster areas (Plates II, III, and IV). A forked mass is found on the mountain slopes at the head of Elijay creek, Macon county, N. C., and a larger one on the spurs of Elk Ridge, in Ashe county. Several others of a similar nature might be added from North Carolina alone.

The planes of least resistance in gneiss lie along the lamination, and hence, as stated above, we should expect the axes of intrusive masses to coincide with these planes. This is found to be true in the great majority of cases, and the apparent exceptions are doubtful. The gneisses and schists bend closely around the enclosed mass, being only temporarily diverted from their normal course. The axes of the bifurcate masses are also found to follow the same general direction. (See Plate III).

The last requirement in geotecnic evidence would seem to be fully met by the gneiss area, more than a quarter of a mile long, entirely surrounded by peridotites, on the northern border of the Webster area. (Pl. IV). Indeed, this Webster region alone, though once made the basis of a theory of sedimentary origin for the peridotites,* affords some of the most conclusive

* "The Dunite Beds of North Carolina," by A. A. Julian, *Proc. Nat. Hist. Soc., Boston*, XXII, 1882, 141-149.

evidence of their intrusive character. The form presented by the lamination planes of the gneiss is that of an eroded dome-shaped anticline, somewhat elongated in almost a north and south direction. Even after considerable observation in the field, it was my impression that the peridotites of this area represented a continuous sheet conformable with the lamination of the gneiss. But close, detailed mapping brought out not only the enclosed body of gneiss mentioned above, but also the irregular, protuberant apophysis at Addie, and other projecting arms at the crossing of Scott's creek, three miles west of Addie, and two in the vicinity of Webster. Furthermore, there are five distinct breaks in the continuity of the eastern side on Cane creek, and the isolated portions have the typical lenticular form found in the majority of the outcrops. In the vicinity of these breaks there is a narrow strip passing off the border of the map in a northeast direction, which is also completely disconnected from the principal masses of this region.

This Webster rock shows the highest development of lamination found in the whole belt, and the microscope shows that the laminated rock is composed of thin layers of finely granulated olivine alternating with coarser typical dunite. This condition, taken in connection with the great development of schistose talc in the narrower portions, gives evidence of considerable shearing, which is most naturally ascribed to the movements that gave rise to the anticlinal structure. The other characters pointed out are explicable only as the results of igneous intrusion.

Much larger areas of gneiss than those enclosed at Webster are almost surrounded in the Buck creek area by the peridotites and the later dikes of amphibolite.

The manner in which these dikes cut the peridotites or pass up through the same opening beside them, both in this region and in a number of places in the adjoining portions of Georgia, clearly indicates that the peridotites occupy areas of weakness in the gneiss, through which the dikes have found their easiest exit. It may be stated here that no direct influence of the amphibolite dikes upon the dunite was noted except an intermingling of the constituents of the two rocks along bands of three or four inches in thickness at the contacts.

Another character which is perhaps as important as that of form, is the entire absence of lamination, or its development to only a slight extent, in the great majority of peridotite outcrops. Dr. Julian, as noted above, studied the outcrop at Webster, where the lamination is so marked that the dunite bears a striking resemblance to a thin-bedded sandstone; and this is, in fact, what Dr. Julian considered it to be. As pointed out by Dr. Wadsworth, however, "the chief defect in Dr. Julian's reasoning is that all the evidence which he gives in support of this view could exist equally well if the rock had some entirely different origin."* If Dr. Julian had only studied some of the typical massive dunite to be found within a day's journey of Webster, it is safe to say that his conclusion on this point would have been entirely different.

Aside from the lamination in the body of the peridotite, there is often abundant evidence that it has been subjected to considerable shearing in the schistose character of the talc along the borders and in the frequent slickensides encountered in the corundum-bearing chlo-

* *Science*, III, 1884, 486, 487.

rite zones. On the other hand, we find many outcrops that present none of these evidences of shearing, but are perfectly massive and structureless; and we must conclude that these represent the least altered condition of the rock. The massive character of the peridotites, with often scarcely a trace of shearing, is wholly incompatible with the theory that they are of contemporaneous origin with the gneiss and have passed through the same cycles of disturbance.

The line of separation between the peridotites and the gneiss is always sharp; there are no transitional forms, either in chemical or mineralogical composition. The peridotites are extremely basic magnesian rocks (40-45 per cent. silica); the constituents of the gneiss are all aluminous minerals, and the rock is highly acid (60-70 per cent silica). That such dissimilar rocks would have been deposited as contemporaneous sediments or precipitates over wide areas without somewhere producing an intermediate type is, at least, highly improbable.

Even a mere casual examination of these rocks with the microscope reveals a thoroughly crystalline granular structure, generally a coarse texture, and in all respects the characteristics of a deep-seated, igneous rock. In fresh specimens the olivine grains always present angular outlines, sometimes having crystal form, and always fitting perfectly together, without interstitial spaces or cementing material of any kind. (Pl. V., fig. 1). In the first stage of alteration to serpentine the grains are separated by thin films of this mineral; but the irregularities of adjacent grains still remain perfect counterparts. (Pl. V, fig. 2.). Only in the more advanced stages do the corners become rounded and the intervening serpentine assume the appearance

PLATE I.

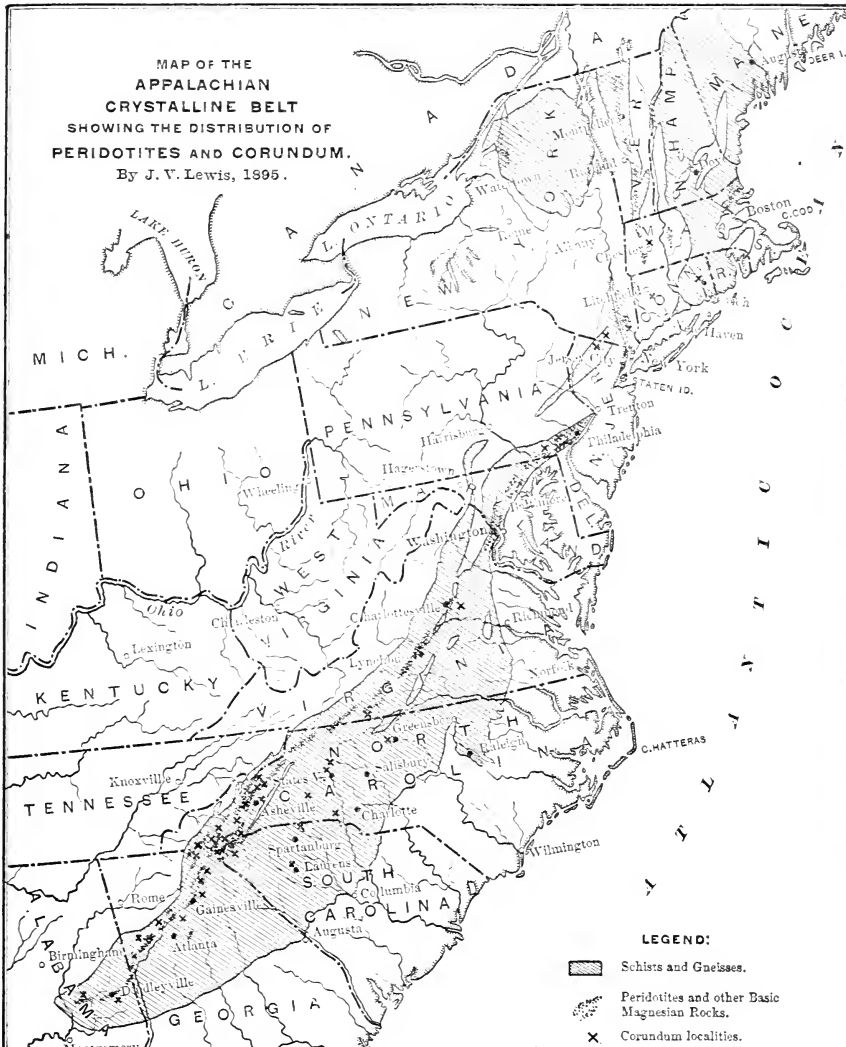
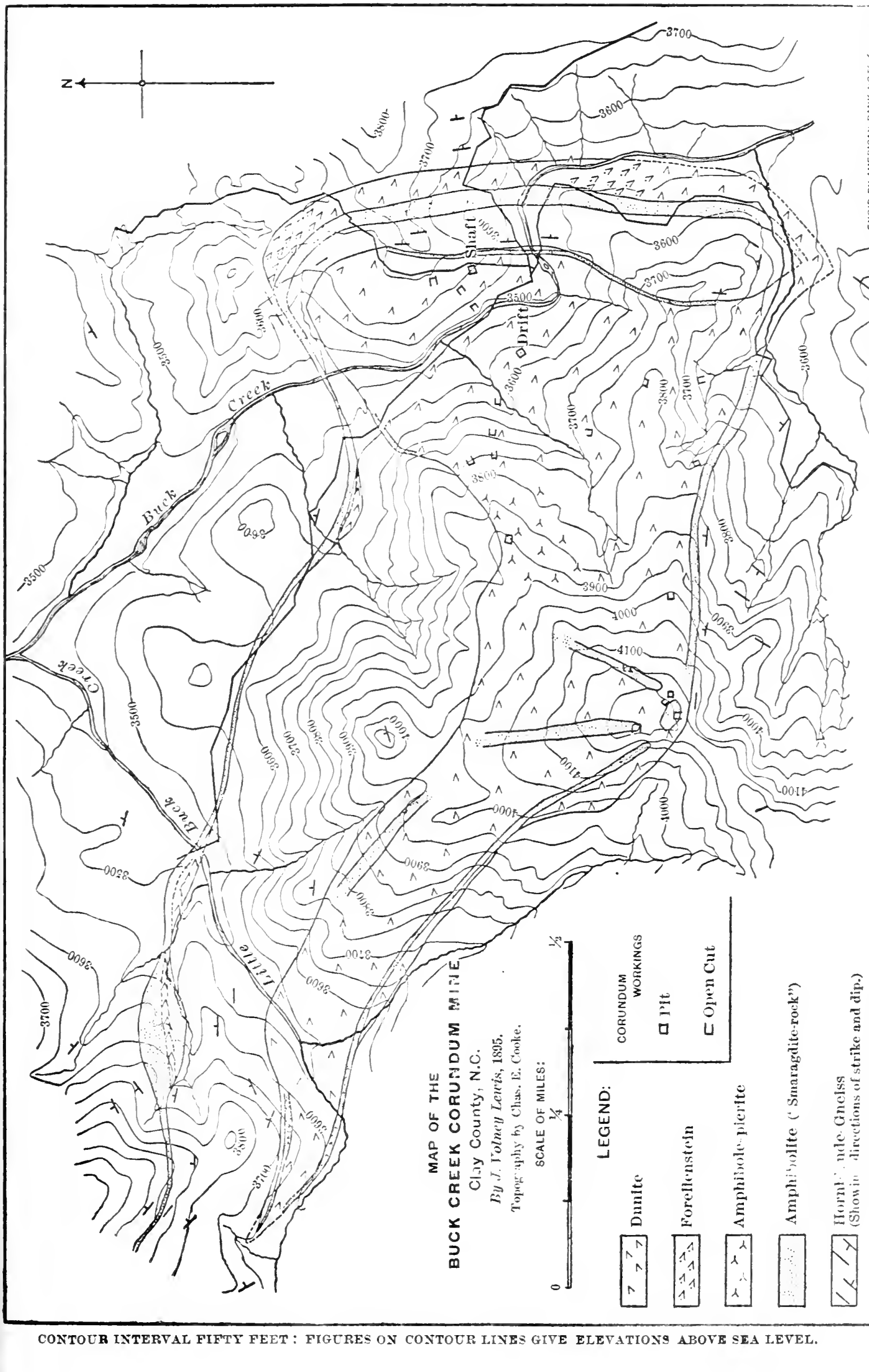
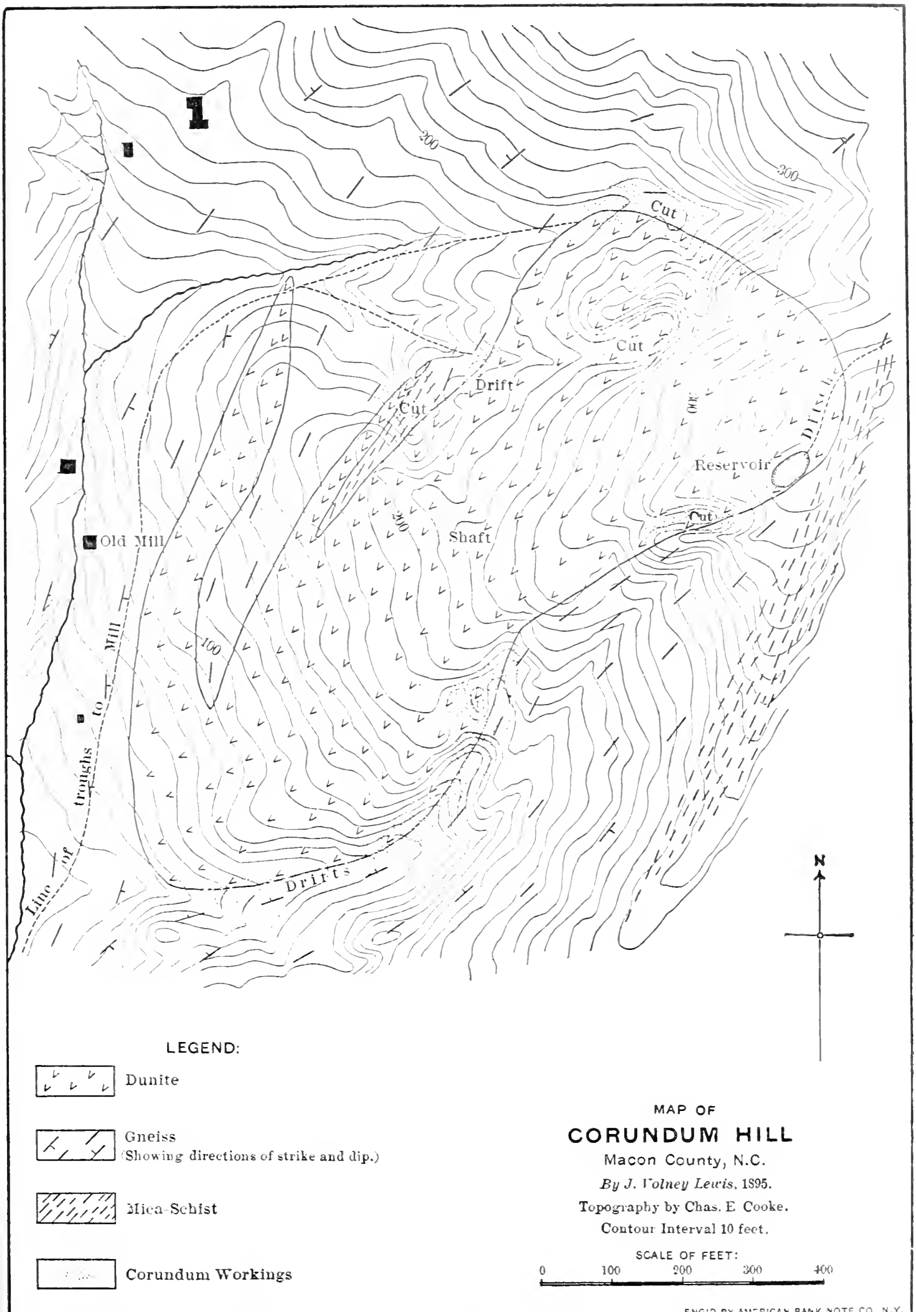

MAP OF THE
APPALACHIAN
CRYSTALLINE BELT
SHOWING THE DISTRIBUTION OF
PERIDOTITES AND CORUNDUM.
By J. V. Lewis, 1895.
LEGEND:
Schists and Gneisses.
Peridotites and other Basic Magnesian Rocks.
Corundum localities.
AM. BANK NOTE CO. N.Y.

PLATE II.

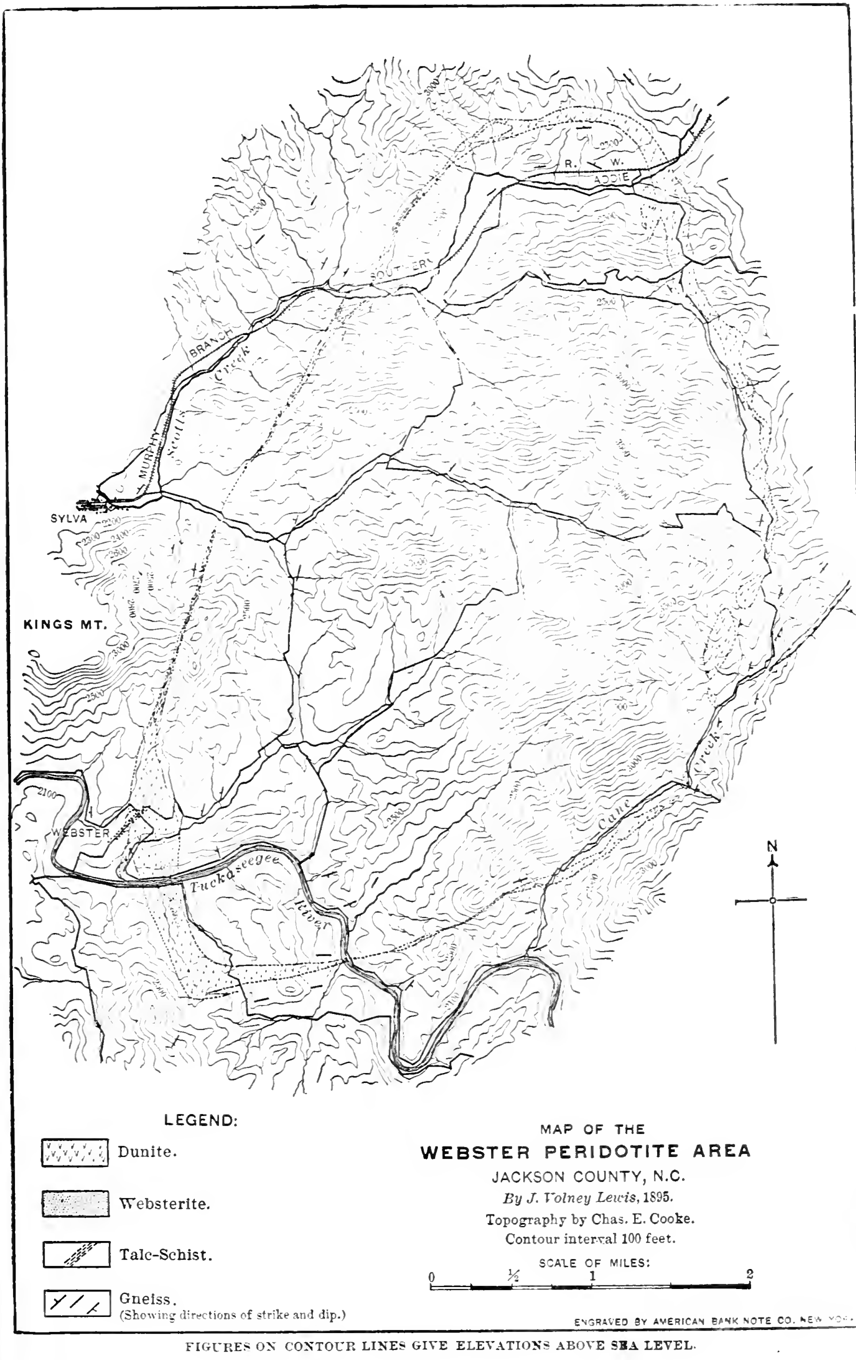


CONTOUR INTERVAL FIFTY FEET: FIGURES ON CONTOUR LINES GIVE ELEVATIONS ABOVE SEA LEVEL.



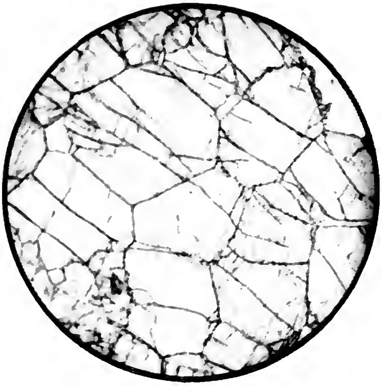
FIGURES ON CONTOUR LINES GIVE ELEVATIONS ABOVE AN ARBITRARY BASE—THE FLAT ROCK BED OF THE BRANCH NEAR THE SOUTHWESTERN CORNER OF THEMAP

PLATE IV

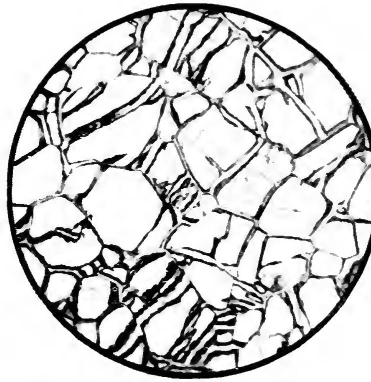


FIGURES ON CONTOUR LINES GIVE ELEVATIONS ABOVE SEA LEVEL.

PLATE V.



1



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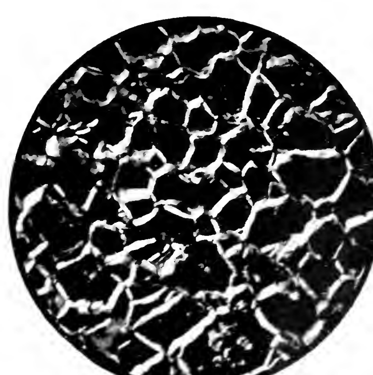

6

of a cementing material in a clastic rock; and this is true only when thin sections are viewed in ordinary light. (Pl. V, fig. 4.) For, so long as numerous oli-ivine remnants remain embedded in the serpentine, they are frequently found to extinguish together over considerable areas, showing that the fragments belong to the same crystalline individual, representing the larger grains of the original rock. Such fragments may be as widely separated by the alteration product as are the portions of entirely distinct individuals. Even after all traces of unaltered olivine have disappeared, the original granular character, and occasionally the outline of a crystal form, are still shown in some of the serpentines by the narrow, reticulating bands ("mesh-structure") of parallel-polarizing, fibrous serpentine, representing the first stage of alteration along the borders and fissures of the olivine grains.

Plate V. is reproduced from photomicrographs of thin sections of typical dunite. A perfectly fresh specimen is shown in figure 1. Figure 2 shows a slight beginning of serpentinization about the borders of the olivine. Figure 3 is taken from a fresh specimen in which the original grains, like those in figure 1, have been broken into great numbers of smaller grains, without perceptibly disturbing their orientation; this section is seen between crossed nicols. A more advanced stage of alteration than that of figure 2 is shown in figure 4; the olivine grains, the light portions of the field, are reduced to mere remnants. Figure 5 represents the final result of serpentinization, in which no fragment of unaltered olivine remains. With the exception of spots caused by segregation of iron oxides, the rock appears perfectly homogeneous in ordinary light. When viewed between crossed nicols, however,

the 'mesh-structure' is distinctly brought out, and the original granular nature of the rock clearly seen, as shown in figure 6.

The variation between the different mineralogic varieties within the same rock mass, and the essential unity of the whole peridotite group, have been pointed out above in the descriptions of the various types. Dunite, harzburgite and enstatite rock are often found to blend into each other as inseparable parts of the same rock mass, with no banding or irregularity of structure, whatever, between the different types. These phenomena are such as are referred to magmatic segregation or differentiation in well recognized igneous rocks. In the enstatite bearing type, the crystals of this mineral are much larger than the grains of olivine and are in the form of broad, flat plates; yet, when the rock has not been sheared, no trace of parallel arrangement has been detected. Even when considerably sheared and laminated, only a partial parallelism has been effected between the enstatites, and they have usually been altered into talc.

Similar transitions from dunite to amphibole-picrite are found within the peridotite area at Buck Creek (Pl. II.). Here, too, and also throughout a considerable territory to the southwest, transitions are found from dunite, the pure olivine rock, to troctolite, the coarse olivine-feldspar type; and the latter, in turn, passes into the pure anorthite rock, anorthosite.

The extremely fresh condition of the olivine, even in the surface exposures, is a very striking feature of these peridotites. Most of them, it is true, show some tendency to serpentinization when examined with the microscope, and in a few cases they have undergone complete transformation; but a number of specimens

have been collected almost at the surface in which scarcely a trace of alteration could be seen. It is well known that olivine is remarkably prone to alteration, either to serpentine, through hydration, or to iron oxides and soluble carbonates, in ordinary surface weathering. Even if it might be conceived that a pre-existing olivine lava had been beaten down by the waves and deposited as beds of sand along the beach, as we are told actually occurs on some of the Hawaiian coasts, it would be extremely difficult to imagine this rock, with all its contained water, placed under conditions necessary to complete solidification into a sandstone, and carried through all the metamorphosing conditions that the enclosing gneisses have certainly undergone, and at last, by erosion to the very heart of the Appalachians, brought to the surface unaltered. With a sandstone of almost pure silica, I can imagine such an evolution possible; but with unstable olivine, the hypothesis seems entirely untenable.

The rapid rate of erosion in the mountain region and the ease with which the granular olivine rock crumbles down under surface weathering, may well account for the freshness of the present exposures. But beds of olivine sand are not formed under these conditions, even in the channels of neighboring streams. Hence, I am led to the conclusion that no theory of sedimentary origin can adequately account for existing conditions, and that these olivine rocks are now practically in the state in which they originally solidified from the molten magma.

SUMMARY OF EVIDENCE.

I have endeavored to show that the peridotites of the South Appalachian region must be regarded as plutonic igneous rocks for the following reasons:

(1) Their blunt, lenticular form is difficult to understand as the result of any kind of sedimentation, but is easily explained when they are considered as small intrusions into a highly laminated rock.

(2) In a number of cases apophyses are sent off into the enclosing gneiss—a condition that can be produced only by igneous action.

(3) In one case, at least, a large block is completely enclosed by the peridotites in such a manner as to preclude all hypotheses of sedimentation, and attributable only to the intrusion of the peridotites in a molten state.

(4) The lamination found in many cases which has been considered true bedding, is always accompanied by abundant evidence of shearing; and this is regarded as the most natural explanation of all such parallel structure in these rocks.

(5) At Buck Creek and in adjoining regions, both the main masses of the peridotites and their apophyses are accompanied by amphibolite dikes, showing that the former occupy positions of marked weakness in the gneisses.

(6) The massive character of the typical outcrops is incompatible with contemporaneous origin with the gneisses; for such character could not have been maintained through the intense metamorphosing processes to which the gneisses have been subjected.

(7) The extremely basic peridotites are enclosed in highly acid gneisses over an extensive territory, but they are everywhere perfectly separate—no transitional types are found.

(8) Under the microscope these peridotites show the typical granular structure of plutonic igneous rocks,

the grains fitting perfectly into each other without interstitial spaces or cementing material.

(9) The mineralogical varieties pass irregularly into each other without interlamination or any regularity of structure whatever. They present typical magmatic differentiation.

(10) The perfectly fresh condition of the olivine, a mineral so prone to alteration, is incompatible with any theory of sedimentation with subsequent solidification, metamorphism and erosion.

Chapel Hill, N. C.,
Feb 1, 1896.

EXPLANATION OF PLATE V.

Fig. 1. Specimen from railroad cut 2 miles west of Balsam Gap, Jackson, Co., N. C.

This is an exceptionally fresh specimen of the pure olivine type. Crystal outlines are rather more common in this section than usual.

Fig. 2. Specimen from Carter Corundum Mine, Madison Co., N. C.

This figure represents the prevailing character of the surface exposures of dunite. The first narrow bands of yellowish green serpentine, which afterwards constitute the 'mesh-structure' have just been formed.

Fig. 3. Specimen from Carter Corundum Mine, Madison Co., N. C.

This section shows a common type of fine grained dunite. It is here seen between crossed nicols, and the extinction together of the fine grains over considerable areas shows that it is essentially a coarse-grained rock, like that shown in Fig. 1.

Fig. 4. Specimen from Webster, Jackson Co., N. C.

This specimen shows an advanced stage in serpentinization, the beginning of which is shown in figure 2. Rejected iron oxides have been deposited in dark bands about the olivine remnants.

Fig. 5. Specimen from Paint Fork, Madison Co., N. C.

No olivine fragments are found in this specimen. Except for the black accumulations of iron oxides, the rock looks homogeneous in ordinary light.

Fig. 6. Specimen the same as for Fig. 5.

This figure is identical with the last, except that it is here seen between crossed nicols. The 'mesh-structure' outlining the original olivine grains is well shown. (The view is inverted with reference to figure 5.)

MONAZITE*

BY H. B. C. NITZE.

During the past two years the mineral monazite has come into considerable prominence, owing to the demand for it in the manufacture of mantles for the incandescent gas light, which is at present creating such wide spread interest the world over.

In Bulletin No. 9 of the North Carolina Geological Survey, 1895, I have published a monograph on the subject of Monazite and the Monazite Deposits of North Carolina, and a similar chapter also appears by me in "The Mineral Resources of the United States," Part IV., Sixteenth Annual Report of the Director of the U. S. Geological Survey, 1894–1895, pp. 667 to 694.

In this place I propose to give a general resumé of monazite, its properties, composition, occurrence and use.

NOMENCLATURE.

The earliest identification of this mineral as a separate species in the mineral kingdom was in 1823, although at that time it was known as "Turnerite." The name monazite was given in 1829, and its meaning —from the Greek—is, "to be solitary," on account of the great rarity of the mineral at that time and long subsequently. Other names for this mineral, given at various times when they were thought to represent separate and distinct species, were mengite, eremite, edwardsite, cryptolite, monazitoid, phosphocerite, ur-

* Published by permission of the State Geologist of North Carolina, who also allows the use of plates prepared for Bulletin 9 of the N. C. Geological Survey.

dite and kararfveite. These were all shown, by the patient investigations of renowned mineralogists, to be identical with monazite, and that name was retained because at the time it was given it represented a crystallographically as well as chemically known mineral, while the attributes of the others were not so well established until later. And so the name monazite is in common use to-day.

CHEMICAL COMPOSITION.

Chemically, monazite is an anhydrous phosphate of cerium, lanthanum and didymium. It also contains, almost invariably, small percentages of thoria and silica; and some of the more complete analyses have shown the presence of yttria, erbia, alumina, ferrous and ferric oxide, lime, magnesia, manganese, tin and lead oxides, fluorine, zirconia, tantalic and titanic acids. Undoubtedly most of these latter existed as impurities, in all probability, attached to the monazite. Below are given a few detailed analyses from various localities.

ANALYSES OF MONAZITE.

	1	2	3	4	5	6	7	8
P_2O_5	28.62	27.07	23.85	27.28	17.94	28.78	26.86	29.28
Ce_2O_3	32.52	25.82	27.73	30.46		27.73	24.80	31.38
La_2O_3	29.41	30.62	21.96	24.37	21.30	39.24	26.41	30.88
Di_2O_3								
Y_2O_3	2.04	2.03	2.86	1.58				
ThO_2	4.54	9.60	9.05	11.57			12.60	6.49
SiO_2	1.51	1.85	5.95	2.02		1.60	.91	1.40
Al_2O_3	.22	.15						
Fe_2O_3	.36	1.01	4.63		trace	1.30	1.07	
FeO				1.10				
MnO		.08		.24				
CaO	.84	.91	4.83	1.05	1.50	.90		
MgO		.03			trace		.04	
ZrO_2			.66				1.54	
SnO_2	.22			.08				
PbO		.58		.26				
Ta_2O_5					6.27			
F								
TiO_2								
H_2O	.27	.35	1.61	.38	1.36		.78	.20
CeO					49.35			
Er_2O_3							4.76	

(1) to (4) inclusive are from pegmatite veins of southern Norway, by C. W. Blomstrand. (5) From Lake Ilmen, Russia, by R. Hermann. (6 From Arendal, Sweden, by C. F. Rammelsberg. (7) From Ottawa County, Quebec, by F. A. Genth. (8) From Burke County, N. C., by S. L. Penfield.

Penfield* deduces the molecular formula:

$$(Ce, La, Di)_2O_3 : P_2O_5 = 1 : 1;$$
$$THO_2 : SiO_2 = 1 : 1.$$

The former corresponds to the normal phosphate of the cerium metals ($R_2P_2O_8$); the latter corresponds to the normal thorium silicate, which, in combination with a small percentage of water, makes the mineral thorite or orangite ($ThSiO_4.H_2O$). He concludes, therefore, that monazite is essentially a normal phosphate of the cerium metals, in which thorium silicate is present in varying proportions as an impurity in the form of the mineral thorite or orangite.

Dunnington† had somewhat previously come to the same conclusion. Rammelsberg's‡ formula of thorium free monazite from Arendal, Norway, was $R_2P_2O_8 = (Ce, La, Di)_2P_2O_8$, thus agreeing with Penfield.

Blomstrand,§ from his analysis of Norwegian and Siberian monazite concludes that the mineral is a normal tri-basic phosphate, an excess of bases being combined with SiO_2. Thus: $m(3RO,P_2O_5) + 2RO,SiO_2 + pH_2O$, where $m = 5$ to 20, and $p =$ less than 1 usually.

He does not believe, as Penfield does, that the thoria is originally combined with silica as thorite, but that

* Am. Jour. Sci. (3) vol. XXIV, 1882, p. 250; vol. XXXVI, 1888, p. 322. Zeitschr. für Kryst., vol, VII, 1883, p. 366; vol. XVII, 1890, p. 407.

† Am. Chem. Jour., vol. IV, 1882, p. 138.

‡ Zeitschr. Deutch. Geol. Gesell. Berlin vol. XXIX, 1877, p. 79.; Zeitschr. für Kryst., vol. III, 1879, p. 101.

§ Zeitschr. für Kryst., vol. IX, 1887, p. 160; vol. XX, 1892, p.367.

it is present as a phosphate, either in combination with the cerium or as an isomorphous mixture, thus:

$$\overset{IV}{Ce}.\overset{III}{Ce}.(O_3PO)_2 \text{ and } \overset{II}{R}.\overset{IV}{Th}(O_3PO)_2;$$

and that it is altered to the silicate by siliceous waters.

PHYSICAL PROPERTIES.

The crystallographic form of monazite is monoclinic, and the commonly occurring planes are ortho- and clino-pinacoids and domes, the unit prism and the unit pyramid. The basal pinacoid is rare, having been observed only on crystals from the Urals and from Alexander County, N. C.

The usual crystal habit is tabular, parallel to the ortho-pinacoid; also short columnar, and sometimes elongated parallel to the prism. Twins are not common, the twinning plane being usually parallel to the ortho-pinacoid.

These crystals vary in size from the microscopic needles of cryptolite, which have a thickness of 0.00015 to 0.00062 inch, to the abnormally large crystals of Amelia County, Va., 5 inches in length. The more general variation lies between $\frac{1}{20}$ and 1 inch.

The cleavage of monazite is most perfectly developed parallel to the basal pinacoid, it is also distinct, as a rule, parallel to the ortho-pinacoid; and sometimes visible parallel to the clino-pinacoid. The mineral is brittle, with a conchoidal to uneven fracture; the hardness is 5 to 5.5; specific gravity 4.64 to 5.3; lustre resinous to waxy; the crystal faces are splendent in fresh, pure specimens, dull in weathered, impure specimens; the color is honey yellow, yellowish brown, amber brown, reddish brown, brown or greenish yellow; the purest specimens are transparent, becoming translucent, and even opaque in the impure varieties.

The optical properties of monazite are:—thin sections, by transmitted light, are colorless to yellowish; pleochroism is generally scarcely noticeable; absorption **b** is greater than **c** = **a**; the plane of the optic axis is perpendicular to the plane of of symmetry, that is the clino-pinacoid, the positive acute bisectrix lies in the oblique angle β, hence sections parallel to the basal pinacoid show the full interference figure; the extinction angle varies from 1°04' to 5°54'; the optical angle is small, 2E (red) = 25°22', 2E (yellow) = 24°56', 2V (yellow) = 12°44', (from Schüttenhofen, Bohemia); the dispersion is weak and horizontal; the single refraction is high, and the double refraction considerable, $\gamma - \alpha = 0.0454$, $\gamma - \beta$ 0.0446, $\beta - \alpha = 0.0008$ (from Arendal, Norway).

DISTRIBUTION AND MODES OF OCCURRENCE.

Until comparatively recently the localities in which monazite was found were few and far between. The original specimen of turnerite came from the Dauphiné in France; in 1826 Menge discovered some crystals in the Ilmen Mountains of Russia; it was then found in the United States at Norwich and Watertown, Conn. Up to the present time, it has been found in over 75 localities in the United States, Canada, South America, England, Sweden, Norway, Finnish Lapmark, Russia, Belgium, France, Switzerland, Germany, Austria and Australia. And the probabilities are that these localities will be rapidly added to in the future.

Monazite is an accessory constituent of the granite eruptives and their derived gneisses. It has been found in these rocks over widely separated areas of the Earth's surface, and further search and study is liable to reveal its more general presence in similar rocks,

than was formerly supposed. Thus Derby,* by examining the heavy residues of a number of hand specimens, selected at random from the collection in the National Museum at Washington, D. C., described the occurrence of monazite in certain granites and gneisses of Maine, New Hampshire, Rhode Island and Massachusetts.

In Norway, Silesia and Bohemia, and in some of the mica mines of Canada, Virginia and North Carolina, monazite has been found in pegmatite dikes. Derby has found the mineral in a red syenite at Serra do Stauba, in the province of Bahia, Brazil. The turnerite of the Saacher Lee (which is an extinct volcanic crater) near Coblenz, in Prussia, was found in a druse in a sanadine bomb, the only known occurrence of monazite in an undoubted volcanic rock.

The turnerite of Olivone, Switzerland, occurs in a quartz vein 20 to 30 cm. wide, traversing crystalline schists.

The cryptolite of Norway occurs as inclusions of very fine, needle-shaped crystals in apatite.

In Cleveland County, N. C., monazite has been found intergrown in cyanite.

The percentage of monazite in these rocks is exceedingly small, often infinitesimal; thus Derby* states that the granite dikes of Serra de Tingua, near Rio, are rich in the yellow mineral, carrying 0.02 to 0.03 per cent, and a fine-grained granite dike on the outskirts of Rio de Janeiro, showed 0.07 per cent monazite.

Monazite has not been found in the sedimentary rocks, although it may be present in some of these as a secondary mineral of transportation.

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* Proc. Rochester Acad. Sci., vol. I, 1891, p. 294.

* Proo. Rochester Acad. Sci. vol. I, 1891, p. 294.

The monazite is contained in the main constituents of the granitic rocks, in the quartz, feldspar and mica, though it appears to be more generally confined to the feldspar.

Zircon may be regarded as a constant associate; among the other usually associated minerals, of coeval origin with the monazite, are xenotine, fergusonite, sphene, rutile, brookite, ilmenite, cassiterite, magnetite, and apatite; sometimes beryl, tourmaline, cyanite, corundum, columbite, samarskite, uraninite, gummite, autunite, gadolinite, hielmite and orthite.

Among the principal secondary minerals found in association with monazite, are rutile, brookite, anatase, epidote, orthite, garnet, sillimanite, and staurolite.

The economically valuable deposits of monazite are found in the placer sands of streams and rivers, in the irregular sedimentary sand deposits of the adjoining bottom lands and in the beach sands along the seashore.

The decomposition and disintegration of the crystalline rocks, the original source of the mineral, has proceeded to considerable depths in certain localities, particularly in the southern unglaciated countries. By erosion and secular movement the material is deposited in the stream beds and there undergoes a natural process of sorting and concentration, the heavy minerals being deposited first and together. The richer portions of these stream deposits are thus found near the headwaters. The accompanying plate shows one of these small valleys (Lattimore's), three miles northeast of Shelby, N. C., where all of the underlying gravel is being dug and washed for monazite (see also plate facing p.), and where the sand in the bed of the small stream is also being washed for the same purpose. The geographical areas over which such work-

able deposits have been found up to the present time, are quite limited in number and exteut.

In the United States the placer deposits of North and South Carolina stand alone. Similar deposits exist in the provinces of Bahia, Minas Geraes, Sao Paulo, and Rio de Janeiro, Brazil; in the river sands of Buenos Ayres, Argentine Republic; in the gold placers of Rio Chico, at Antioquia, Colombia; and in the Bakakui placers of the Sanarka River, Russia. In Brazil there are also important deposits in the beach sands in the southern part of the province of Bahia, near the island of Alcobaca.

But little reliable information is at hand concerning these foreign deposits, and the remainder of the present paper will be taken up with a description of the Carolinian deposits, and the methods of mining and cleaning the sand, employed there.

The Carolinian area includes between 1600 and 2000 square miles, situated in Burke, McDowell, Rutherford, Cleveland, and Polk Counties, N. C., and the northern part of Spartanburg County, S. C. The principal deposits of this region are found along the waters of Silver, South Muddy, and North Muddy creeks, and Henry's and Jacob's forks of the Catawba River in McDowell and Burke counties; the Second Broad River in McDowell and Rutherford counties; and the First Broad in Rutherford and Cleveland counties, N. C., and Spartanburg County, S. C. These streams have their source in the South Mountains, an eastern outlier of the Blue Ridge. The general outlines of this area are indicated on the accompanying map.

The country rock is granitic biotite gneiss and dioritic hornblende gneiss. The existence of monazite

here in commercial quantities was first established in 1887. The thickness of these stream gravel deposits is from one to two feet. The percentage of monazite in the original sand is very variable, from an infinitesimal quantity to one or two per cent.

WASHING AND CLEANING MONAZITE SAND.

The monazite is won by washing the material in sluice boxes, about 8 feet long by 20 inches wide by 20 inches deep, exactly after the manner that placer gold is worked. Magnetite, if present, is eliminated from the dried, concentrated sand by treatment with a large hand magnet. Many of the heavy minerals such as zircon, menaccanite, rutile, brookite, corundum, garnet, etc., cannot at present be completely separated. The commercially prepared sand, therefore, is not *pure* monazite. A cleaned sand, containing from 65 to 70 per cent. monazite is considered of good quality.

The most systematic washing method employed is by the use of two sluice boxes, the mouth of one discharging into the head of the other, placed below. The gravel is charged on a perforated plate at the head of the upper box, and the clean up is so thoroughly washed as to give a high grade sand, often up to 85 per cent. pure. The tailings discharge directly into the lower box, where they are rewashed, producing a second grade sand. At times the material is subjected to as many as five similar consecutive washing treatments in the sluice boxes. A further concentration of the dried washed sand is sometimes made by pouring from a cup in a fine, steady stream from a height of about 4 feet, on to a level platform; the lighter quartz and black sand, with the fine grains of monazite (tailings) fall on the periphery of the conical pile and are constantly brushed aside with hand brushes; these tailings are

afterwards rewashed. Or, instead of pouring and brushing, the material is treated in a winnowing machine, similar to that used for separating chaff from wheat.

Although the best grade of sand, produced by the above complicated treatment, may be as high as 85 per cent. pure, its quantitative proportion is small as compared with the second and other inferior grades, and there is always considerable loss of monazite in the final tailings. It is impossible to conduct this washing process without loss in monazite, and equally impossible to make a *perfect* separation of the garnet, rutile, titanic iron ore, etc., even in the best grades.

But very few regular mining operations are carried on in the region. As a rule each farmer mines his own monazite deposit and sells the product to local buyers, often at some country store in exchange for merchandise.

At the present time the monazite in the stream beds has been practically exhausted, with few exceptions, and the majority of the washings are in the gravel deposits of the adjoining bottoms. These deposits are mined by sinking pits, about 8 feet square to the bed rock, and raising the gravel by hand labor to a sluice-box at the mouth of the pit. The overlay is thrown away, excepting in cases where it contains any sandy or gritty material, when it is also washed. The pits are carried forwards in parallel lines, separated by narrow belts of tailings dumps, as shown by the accompanying illustrations taken from the Lattimore mine, three miles N.E. of Shelby, Cleveland County.

It has been shown that the monazite occurs as an accessory constituent of the country rock, and that the latter is decomposed to considerable depths, sometimes

as much as 100 feet. On account of the minute percentage of monazite in the mother rock, it is usually impracticable to economically work the same in place, by such a process of hydraulicking and sluicing for instance.

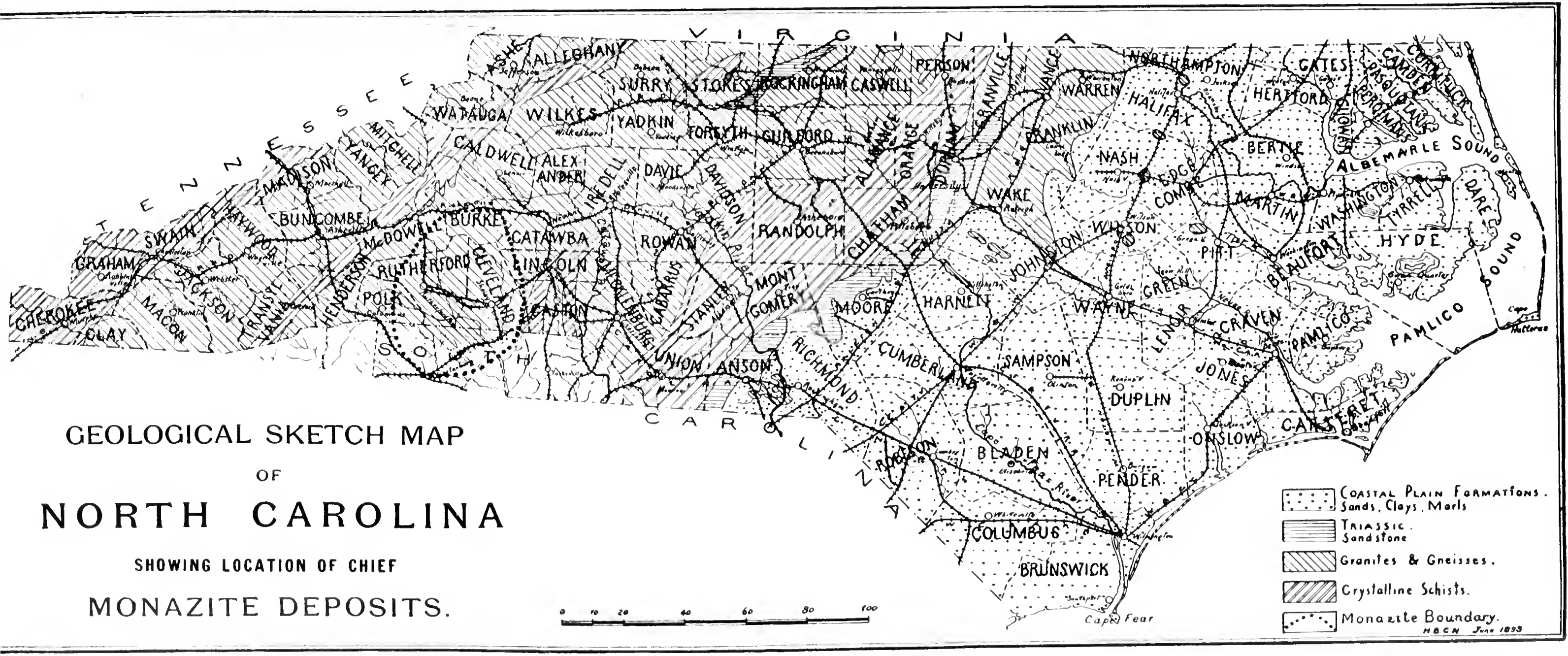
However, hillside mining of surface soil to depths of 4 to 6 feet, has been carried on in certain localities with apparent success. The material is transported in wheelbarrows to washing boxes situated below a water race, as shown in the accompanying illustration from the Pheifer mine, three miles east of Shelby. The resulting monazite product is very clean, and the cost of digging and washing the soil is even less, at times, than that in working the lowland gravels.

The value of monazite is more or less dependent on the percentage of thorium which it contains, as this is the element of greatest value in the manufacture of the incandescent mantles. As the percentage of thoria varies in different sands, the value of the sand consequently varies in a measure also. There is no method of determining even the probable percentage of thoria, excepting by careful chemical analysis. Some monazite contains practically no thoria. The best Carolina sand runs from 2 to as high as 6 per cent. thoria.

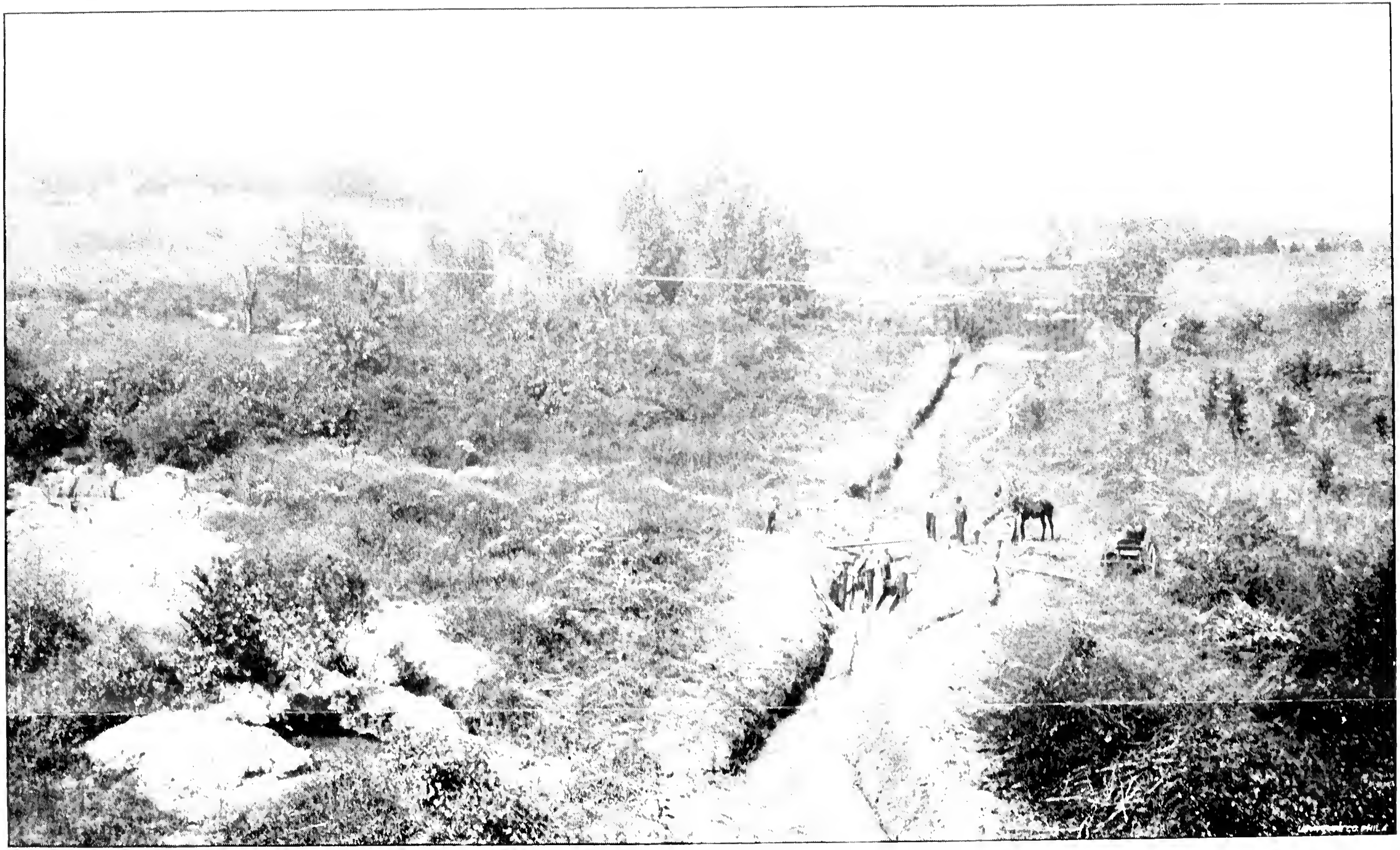
The price of Carolina monazite has varied from 25 cents per pound in 1887, to as low as 3 cents for inferior grades and 6 to 10 cents for the best grades in 1894 and 1895.

The production and value of Carolina sand for the past three years was as follows:

1893		1894		1895	
Amount	Value	Amount	Value	Amount	Value
130,000 lbs	$7,600	546,855	$36,194	1,573,000	$137,150



WORKABLE MONAZITE AREA IN NORTH CAROLINA.



WASHING GRAVEL AND SAND IN STREAM BEDS FOR MONAZITE, LATTIMORE MINE.

THIS VALLEY, 3 MILES N. E. OF SHELBY, IS 100 TO 200 YARDS WIDE, AND ITS UNDERLYING GRAVEL EVERYWHERE YIELDS MONAZITE.

MINING AND WASHING GRAVEL BEDS FOR MONAZITE, LATTIMORE MINE.

THE GRAVEL 2-4 FEET THICK, LIFS ON GRAY GNEISS, AND IS IN TURN OVERLAIN BY 2-4 FEET OF SAND AND LOAM.

DIGGING AND WASHING HILL-SIDE SOIL FOR MONAZITE.

PHEIFER MINE, 3 MILES N. E. OF SHELBY. THE SOIL, 1-4 FEET THICK, HAS BEEN FORMED FROM MONAZITE BEARING GNEISS, IN PLACE.

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